Attorney Dkt. No. 71516-2

TITLE: SOLID STATE SILICON-BASED CONDENSER MICROPHONE

IDENTIFICATION OF INVENTORS:

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Solid state silicon-based condenser microphone

Field of the invention

This invention related to miniature condenser microphones, and in particular to solid state silicon-based condenser microphones incorporating an integrated electronic circuit for transducer signal conditioning. Such miniature microphones are suitable for use in miniature electroacoustic devices such as hearing instruments.

Background of the invention

In the hearing instruments industry one of the primary goals is to make hearing instruments of small size while still maintaining good electroacoustic performance and operability giving good user friendliness and satisfaction. Technical performance data comprise such as sensitivity, stability, compactness, robustness and insensitivity to electromagnetic interference and to other external and environmental conditions. In the past, several attempts have been made to make microphones smaller while still maintaining good technical performance data.

EP 561 566 discloses a solid state condenser microphone having a transducer chip and, on the same chip, an electronic circuit and a cavity forming an opening or sound inlet for the transducer. The techniques and processes for manufacturing such electronic circuitry are quite different from the techniques and processes used in manufacturing the transducer elements. Consequently a chip having both an electronic circuit and an opening therein requires two (or possibly more) separate stages of production, usually at different facilities.

Summary of the invention

The invention provides a solid state silicon-based condenser microphone which is suitable for batch production.

Several silicon chips are stacked, and the subsequent dicing of the stacked chips or discs is easier than with the prior art.

The invention makes it possible to make a very well defined sound inlet, which can optionally be covered with a sealing film or a filter preventing dust, moisture and other impurities from contaminating or obstructing the interior and the sound inlet of the microphone. A sound inlet can theoretically be made as an opening in any of the chip surfaces including the fractures after dicing, but in practice the fractures are irregular surfaces and therefore less suitable for supporting a sealing film or a filter, since the irregular fractures could give rise to the sealing film or a filter becoming wrinkled and having leakages at its periphery where it is secured to the die surface. A microphone according to the invention has an opening forming a sound inlet in the practically perfectly flat and polished faces of the wafer on which several individual microphones are arranged.

An integrated electronic circuit chip can be arranged on the same plane surface, which is perfectly suited for flip-chip mounting the electronic circuit chip.

An intermediate chip is arranged between the electronic circuit chip and the transducer chip. The intermediate chip has another opening with feedthrough electrical connections on a surface of the opening. The feedthrough connections establish electrical connections between the transducer element on the transducer chip and the electronic circuit chip. This gives a high degree of freedom in designing both the transducer chip and the electronic circuit chip and in particular their electrical terminations.

External electrical connections can be established economically and reliably, and thermal stresses can be avoided with the small size solid state silicon-based condenser microphone of the invention.

The invention uses a separate integrated electronic circuit chip, preferably a CMOS ASIC (Application Specific Integrated Circuit) which can be designed and manufactured separately and independent of the design and manufacture of the transducer portion of the microphone. This is advantageous since the techniques and processes for manufacturing integrated electronic circuit chips are different from those used in manufacturing transducer elements, and each production stage can thus be optimised individually and independent of each other.

Brief description of the drawings

In the following the invention will be explained with reference to the drawings, in which:

Figure 1 is a cross section of a microphone according to the invention, and

Figure 2 is an enlarged view of a portion of the microphone in figure 1.

In the figures, for illustrative purposes, dimensions such as material thickness and mutual distances and possibly other proportions are not necessarily drawn to the same scale.

Detailed description of the invention

The illustrated microphone has the following structure. A silicon transducer chip 1 with a central opening etched therein carries a diaphragm 12 and a backplate 13 covering the central opening in the transducer chip. In this

context the term "backplate" means a structural element which is relatively rigid as compared to the associated diaphragm, which in turn is relatively moveable. The backplate can be placed on either side of the diaphragm. The transducer chip with the diaphragm 12 and a backplate 13 are preferably manufactured as described in the co-pending Danish patent application PA 199800671. The transducer chip 1 and a backchamber-chip 17 having a cavity etched therein, and together the transducer chip 1 and the backchamber-chip 17 form a closed backchamber 11 with the diaphragm 12 forming one wall of the backchamber 11. The diaphragm 12 and the backplate 13 are both electrically conductive or semi-conductive and are arranged parallel and in close proximity to each other and with a well defined air gap in between, so that they form an electrical capacitor.

The backplate 13 has a plurality of perforations 19 making it acoustically transparent, and the diaphragm has a tiny vent hole 15 for equalising the static pressure on both sides of the diaphragm.

An electronic circuit chip 3 having an integrated circuit on a surface thereof is flip chip mounted with its circuit facing the transducer chip 1 and with an intermediate chip 2 between the transducer chip 1 and the electronic circuit chip 3. The intermediate chip 2 has a cavity 10 and a first through going opening 4 and a second through going opening 18 both communicating with the cavity 10. The intermediate chip 2 is secured to the transducer chip 1 by means of an electrically conductive solder ring 9 or by other means.

The electronic circuit chip 3 is secured to the intermediate chip 2 by means of an underfill material 6.

The diaphragm 12 and the backplate 13 are electrically connected to respective ones of solder bumps 8, which connect the diaphragm 12 and the backplate 13 to electrical feedthrough conductors 14 on the surface of the cavity 10 and the opening 18 and further to the upper surface of the intermediate chip 2 where connections to the electronic circuit chip 3 are established via a conventional flip-chip interconnect method e.g. gold studs 7 with conductive adhesive. This is most clearly seen in figure 2.

The opening 4 is covered with a filter 5 or a flexible sheet or diaphragm of acoustically transparent material. The whole structure is encapsulated in a polymer encapsulation 16 leaving the filter 5 free.

The function of the above described structure is as follows. The opening 4 functions as a sound inlet, and ambient sound pressure enters through the filter 5 covering the opening 4 to the cavity 10 functioning as a front chamber for the microphone. Through the perforations 19 in the backplate 13 the sound pressure reaches the diaphragm 12. The cavity 11 functions as a backchamber for the microphone. The diaphragm 12 is movable relative to the backplate 13 in response to incident sound. When the diaphragm is moved in response to the incident sound, the electrical capacity of the electrical capacitor formed by the diaphragm 12 and the backplate 13 will vary in response to the incident sound. The circuit on the integrated circuit chip 3 is electrically connected to the diaphragm 12 And the backplate 13 via the electrical feedthrough conductors 14, and the circuit is designed to detect variations in the electrical capacity of the capacitor formed by the diaphragm 12 and the backplate 13. The circuit has electrical connections for electrically

connecting it to a power supply and other electronic circuitry in eg a hearing instrument.

In the illustrated embodiment the transducer element on the transducer chip is a condenser microphone with a diaphragm and a single backplate. In an alternative embodiment the transducer element has its diaphragm arranged between two backplates. Such a microphone can give balanced output signal which is less sensitive to electrical interference.